

WHAT IS CLAIMED IS:

1 1. A method of estimating a position of a mobile
2 terminal operating in a coverage area of a radio
3 telecommunications network having a plurality of base
4 station transceivers and a plurality of service area
5 sectors, said method comprising the steps of:

6 determining, for a plurality of positions throughout
7 the coverage area of the network, expected Received
8 Signal Strength (RSS) values of a signal transmitted by
9 the base station transceivers and received by a typical
10 mobile terminal;

11 storing the expected RSS values at a plurality of
12 locations in a database;

13 obtaining, by the mobile terminal for which the
14 position is to be estimated, RSS measurements of signals
15 transmitted by the base station transceivers;

16 comparing the RSS measurements obtained from the
17 mobile terminal with the expected RSS values stored in
18 the database; and

19 estimating the position of the mobile terminal based
20 on differences between the RSS measurements and the
21 expected RSS values.

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1 2. The method of estimating a position of a mobile
2 terminal of claim 1 wherein the step of determining
3 expected RSS values for a plurality of positions
4 throughout the coverage area of the network includes
5 predicting the expected RSS values with a computer-aided
6 prediction tool.

1 3. The method of estimating a position of a mobile
2 terminal of claim 2 wherein the step of predicting the
3 expected RSS values with a computer-aided prediction tool
4 includes predicting the expected RSS values with a
5 computer-aided prediction model that considers the effect
6 of terrain and clutter on the expected RSS values.

1 4. The method of estimating a position of a mobile
2 terminal of claim 1 wherein the step of determining
3 expected RSS values for a plurality of positions
4 throughout the coverage area of the network includes
5 taking a plurality of actual measurements of the RSS of
6 signals transmitted by the base station transceivers and
7 received by a test mobile terminal.

1 5. The method of estimating a position of a mobile
2 terminal of claim 1 wherein the step of determining
3 expected RSS values for a plurality of positions
4 throughout the coverage area of the network includes

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5 taking a plurality of actual measurements of the RSS of
6 a signal transmitted by a test mobile terminal and
7 received by the base station transceivers.

1 6. The method of estimating a position of a mobile
2 terminal of claim 1 wherein the step of determining
3 expected RSS values for a plurality of positions
4 throughout the coverage area of the network includes the
5 steps of:

6 predicting the expected RSS values for a first
7 portion of the positions with a computer-aided prediction
8 tool; and

9 taking actual measurements of the RSS of signals
10 transmitted by the base station transceivers and received
11 by a test mobile terminal for a second portion of the
12 positions.

1 7. The method of estimating a position of a mobile
2 terminal of claim 6 wherein the step of storing the
3 expected RSS values in a database includes storing an
4 indicator for each value indicating whether each stored
5 value is a predicted value or a measured value.

1 8. The method of estimating a position of a mobile
2 terminal of claim 7 wherein the step of comparing the RSS
3 measurements obtained from the mobile terminal with the
4 expected RSS values stored in the database includes the
5 steps of:

6 associating a covariance matrix with each of the
7 locations in the database;

8 extracting a sub-matrix of the covariance matrix
9 whose columns and rows correspond to sectors that are
10 common between the sectors stored for the locations in
11 the database and the sectors for which the RSS
12 measurements were obtained from the mobile terminal;

13 calculating, for each location in the database, a
14 probability that RSS measurements are obtained, given
15 that the mobile terminal is at that location; and

16 computing metrics for each location in the database
17 utilizing the calculated probability and a second
18 probability that the mobile terminal is located at the
19 corresponding position.

1 9. The method of estimating a position of a mobile
2 terminal of claim 7 wherein the step of comparing the RSS
3 measurements obtained from the mobile terminal with the
4 expected RSS values stored in the database includes the
5 steps of:

6 associating a first covariance matrix with each of
7 the locations in the database that are populated with
8 measured values, said first matrix containing rows
9 corresponding to all sectors for which measurements are
10 stored in the database for that location;

11 associating a second covariance matrix with each of
12 the locations in the database that are populated with
13 predicted values, said second matrix containing rows
14 corresponding to all sectors for which measurements are
15 stored in the database for that location;

16 determining from the stored indicator, whether the
17 location in the database was populated with a measured
18 value or a predicted value;

19 selecting the first covariance matrix if the
20 location was populated with a measured value;

21 selecting the second covariance matrix if the
22 location was populated with a predicted value;

23 extracting a sub-matrix of the selected covariance
24 matrix whose columns and rows correspond to sectors that
25 are common between the sectors stored for a location in
26 the database and the sectors from which the RSS
27 measurements were obtained from the mobile terminal;

28 calculating, for each location in the database, a
29 probability that RSS measurements are obtained, given
30 that the mobile terminal is at that location; and

31 computing metrics for each location in the database
32 utilizing the calculated probability and a second
33 probability that the mobile terminal is located at the
34 corresponding position.

1 10. The method of estimating a position of a mobile
2 terminal of claim 7 wherein the step of storing the
3 expected RSS values at a plurality of locations in the
4 database includes storing, for each location in the
5 database, an expected measurement variance for each
6 service sector; and the step of comparing the RSS
7 measurements obtained from the mobile terminal with the
8 expected RSS values stored in the database includes the
9 steps of:

10 weighting the RSS measurements obtained from the
11 mobile terminal with the expected measurement variance
12 for the mobile terminal's service sector; and
13 comparing the weighted RSS measurements with the
14 expected RSS values stored in the database.

1 11. The method of estimating a position of a mobile
2 terminal of claim 7 wherein the step of storing the
3 expected RSS values at a plurality of locations in the
4 database includes the steps of:

5 storing in the database for each service sector, a
6 first expected measurement variance for all locations in
7 the database that are populated with measured values; and
8 storing in the database for each service sector, a
9 second expected measurement variance for all locations in
10 the database that are populated with predicted values.

1 12. The method of estimating a position of a mobile
2 terminal of claim 11 wherein the step of comparing the
3 RSS measurements obtained from the mobile terminal with
4 the expected RSS values stored in the database includes
5 the steps of:

6 weighting the RSS measurements obtained from the
7 mobile terminal with the first expected measurement
8 variance if the locations in the database being used for
9 the comparing step are populated with measured values;

10 weighting the RSS measurements obtained from the
11 mobile terminal with the second expected measurement
12 variance if the locations in the database being used for
13 the comparing step are populated with predicted values;
14 and

15 comparing the weighted RSS measurements with the
16 expected RSS values stored in the database.

1 13. The method of estimating a position of a mobile
2 terminal of claim 7 wherein the step of storing the
3 expected RSS values at a plurality of locations in the
4 database includes the steps of:

5 storing, for the entire database, a first expected
6 measurement variance for all locations in the database
7 that are populated with measured values; and

8 storing, for the entire database, a second expected
9 measurement variance for all locations in the database
10 that are populated with predicted values.

1 14. The method of estimating a position of a mobile
2 terminal of claim 13 wherein the step of comparing the
3 RSS measurements obtained from the mobile terminal with
4 the expected RSS values stored in the database includes
5 the steps of:

6 weighting the RSS measurements obtained from the
7 mobile terminal with the first expected measurement
8 variance for locations in the database that are populated
9 with measured values;

10 weighting the RSS measurements obtained from the
11 mobile terminal with the second expected measurement
12 variance for locations in the database that are populated
13 with predicted values; and

14 comparing the weighted RSS measurements with the
15 expected RSS values stored in the database.

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1 15. The method of estimating a position of a mobile
2 terminal of claim 7 wherein the step of estimating the
3 position of the mobile terminal based on differences
4 between the RSS measurements and the expected RSS values
5 includes the steps of:

6 determining whether the percentage of locations in
7 the database being considered as candidates for the
8 location of the mobile terminal that are populated with
9 actual measurements exceeds a predefined threshold; and

10 upon determining that the percentage of locations
11 populated with actual measurements exceeds the predefined
12 threshold:

13 discarding the RSS values that are predicted
14 values; and

15 utilizing an estimator based on a maximum-
16 likelihood criterion to estimate the position.

1 16. The method of estimating a position of a mobile
2 terminal of claim 7 wherein the step of estimating the
3 position of the mobile terminal based on differences
4 between the RSS measurements and the expected RSS values
5 includes the steps of:

6 determining whether the percentage of locations in
7 the database being considered as candidates for the

8 location of the mobile terminal that are populated with
9 actual measurements exceeds a predefined threshold;

10 utilizing an estimator based on a maximum-likelihood
11 criterion to estimate the position, upon determining that
12 the percentage of locations populated with actual
13 measurements exceeds the predefined threshold; and

14 utilizing an estimator based on a minimum-mean-
15 square-error criterion to estimate the position, upon
16 determining that the percentage of locations populated
17 with actual measurements does not exceed the predefined
18 threshold.

1 17. The method of estimating a position of a mobile
2 terminal of claim 7 wherein the step of estimating the
3 position of the mobile terminal based on differences
4 between the RSS measurements and the expected RSS values
5 includes the steps of:

6 determining whether the percentage of locations in
7 the database that are populated with actual measurements
8 exceeds a first predefined threshold;

9 upon determining that the percentage of locations
10 populated with actual measurements exceeds the first
11 predefined threshold:

12 discarding the RSS values that are predicted
13 values; and

14 utilizing an estimator based on a maximum-
15 likelihood criterion to estimate the position;

16 upon determining that the percentage of locations
17 populated with actual measurements does not exceed the
18 first predefined threshold:

19 determining whether the percentage of locations
20 populated with actual measurements exceeds a second
21 predefined threshold that is lower than the first
22 threshold;

23 utilizing the estimator based on the maximum-
24 likelihood criterion to estimate the position, upon
25 determining that the percentage of locations populated
26 with actual measurements exceeds the second predefined
27 threshold; and

28 utilizing an estimator based on a minimum-mean-
29 square-error criterion to estimate the position, upon
30 determining that the percentage of locations populated
31 with actual measurements does not exceed the second
32 predefined threshold.

1 18. The method of estimating a position of a mobile
2 terminal of claim 1 further comprising, prior to
3 comparing the RSS measurements obtained from the mobile
4 terminal with the expected RSS values stored in the
5 database, the step of selecting particular expected RSS
6 values for particular locations in the database based on

7 the mobile terminal's serving sector, and wherein the
8 step of comparing the RSS measurements includes comparing
9 the RSS measurements obtained from the mobile terminal
10 with the particular expected RSS values selected from the
11 database.

1 19. The method of estimating a position of a mobile
2 terminal of claim 18 wherein the step of selecting
3 particular expected RSS values for particular locations
4 in the database based on the mobile terminal's serving
5 sector also includes selecting particular expected RSS
6 values based on the RSS received at the mobile terminal
7 from the mobile terminal's serving base station
8 transceiver, and based on the number of base station
9 transceivers neighboring the serving sector.

1 20. A method of estimating a position of a mobile
2 terminal operating in a coverage area of a radio
3 telecommunications network having a plurality of base
4 station transceivers and a plurality of service sectors,
5 said method comprising the steps of:

6 determining, for a plurality of positions throughout
7 the coverage area of the network, expected Received
8 Signal Strength (RSS) values of a signal transmitted by
9 the base station transceivers and received by a typical
10 mobile terminal, said determining step comprising:

11 predicting the expected RSS values for a first
12 portion of the positions with a computer-aided prediction
13 tool; and

14 taking actual measurements of the RSS of
15 signals transmitted by the base station transceivers and
16 received by a test mobile terminal for a second portion
17 of the positions;

18 storing the expected RSS values at a plurality of
19 locations in a database with an indicator for each
20 location indicating whether each stored value is a
21 predicted value or a measured value, said storing step
22 including:

23 storing in the database, for each service
24 sector, a first expected measurement variance for all
25 locations in the database that are populated with
26 measured values; and

27 storing in the database, for each service
28 sector, a second expected measurement variance for all
29 locations in the database that are populated with
30 predicted values;

31 obtaining, by the mobile terminal for which the
32 position is to be estimated, RSS measurements of signals
33 transmitted by the base station transceivers;

34 weighting the RSS measurements obtained by the
35 mobile terminal with the first expected measurement

36 variance for locations in the database that are populated
37 with measured values;

38 weighting the RSS measurements obtained by the
39 mobile terminal with the second expected measurement
40 variance for locations in the database that are populated
41 with predicted values; and

42 comparing the weighted RSS measurements with the
43 expected RSS values stored in the database;

44 estimating the position of the mobile terminal based
45 on differences between the weighted RSS measurements and
46 the expected RSS values, said estimating step comprising:

47 determining whether the percentage of locations
48 being considered in the database that are populated with
49 measured values exceeds a predefined threshold;

50 utilizing an estimator based on a maximum-
51 likelihood criterion to estimate the position, upon
52 determining that the percentage of locations being
53 considered in the database that are populated with
54 measured values exceeds the predefined threshold; and

55 utilizing an estimator based on a minimum-mean-
56 square-error criterion to estimate the position, upon
57 determining that the percentage of locations being
58 considered in the database that are populated with
59 measured values does not exceed the predefined threshold.

1 21. A system for estimating a position of a mobile
2 terminal operating in a coverage area of a radio
3 telecommunications network having a plurality of base
4 station transceivers and a plurality of service sectors,
5 said system comprising:

6 means for determining expected Received Signal
7 Strength (RSS) values of signals transmitted by the base
8 station transceivers and received by a typical mobile
9 terminal for a plurality of positions throughout the
10 coverage area of the network;

11 means for storing the expected RSS values at a
12 plurality of locations in a database;

13 means for measuring by the mobile terminal for which
14 the position is to be estimated, the RSS of signals
15 transmitted by the base station transceivers; and

16 means for comparing the RSS measurements obtained by
17 the mobile terminal with expected RSS values, and
18 estimating the position of the mobile terminal based on
19 differences between the RSS measurements and the expected
20 RSS values.

1 22. The system for estimating the position of a
2 mobile terminal of claim 21 wherein the means for
3 determining expected RSS values includes:

4 a computer-aided prediction tool that predicts the
5 expected RSS values for a first portion of the positions;
6 and

7 a test mobile terminal that measures the RSS of test
8 signals received from the base station transceivers for
9 a second portion of the positions.

1 23. The system for estimating a position of a
2 mobile terminal of claim 22 wherein the means for
3 comparing the RSS measurements obtained by the mobile
4 terminal with expected RSS values, and estimating the
5 position of the mobile terminal is a positioning
6 algorithm that includes:

7 means for computing a metric for each location in
8 the database; and

9 means for estimating the position of the mobile
10 terminal using the computed metrics and *apriori*
11 probabilities for each position.

1 24. The system for estimating a position of a
2 mobile terminal of claim 23 wherein the means for
3 computing a metric for each location in the database
4 includes means for computing a different metric for each
5 location, depending upon whether the location is
6 populated with a predicted value or a measured value from
7 the test mobile terminal.

1 25. The system for estimating a position of a
2 mobile terminal of claim 24 wherein the means for
3 estimating the position of the mobile terminal using the
4 computed metrics and the apriori probabilities for each
5 location includes:

6 an estimator based on a maximum-likelihood
7 criterion;

8 an estimator based on a minimum-mean-square-error
9 criterion; and

10 means for selecting the estimator based on the
11 maximum-likelihood criterion if the percentage of
12 locations in the database that are populated with actual
13 measurements exceeds a predefined threshold, or for
14 selecting the estimator based on the minimum-mean-square-
15 error criterion if the percentage of locations in the
16 database that are populated with actual measurements does
17 not exceed the predefined threshold.

1 26. A method of populating a database with expected
2 Received Signal Strength (RSS) values for a typical
3 mobile terminal operating in a coverage area of a radio
4 telecommunications network having a plurality of base
5 station transceivers that transmit radio signals received
6 by the mobile terminal, said method comprising the steps
7 of:

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8 determining, for a plurality of positions throughout
9 the coverage area of the network, expected RSS values of
10 a signal transmitted by the base station transceivers and
11 received by the typical mobile terminal, said determining
12 step comprising the steps of:

13 predicting the expected RSS values for a first
14 portion of the positions with a computer-aided prediction
15 tool; and

16 taking actual measurements of the RSS of
17 signals transmitted by the base station transceivers and
18 received by a test mobile terminal for a second portion
19 of the positions; and

20 storing the predicted and measured expected RSS
21 values at a plurality of locations in the database.

1 27. The method of populating a database of claim 26
2 further comprising tagging each location in the database
3 to indicate whether the stored RSS value is a predicted
4 value or a measured value.